National Aeronautics and
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Jet Propulsion Laboratory
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Machine Learning Approaches for General Satellite Maneuvers

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November 28th 2018 NASA Goddard Workshop

National Aeronautics and
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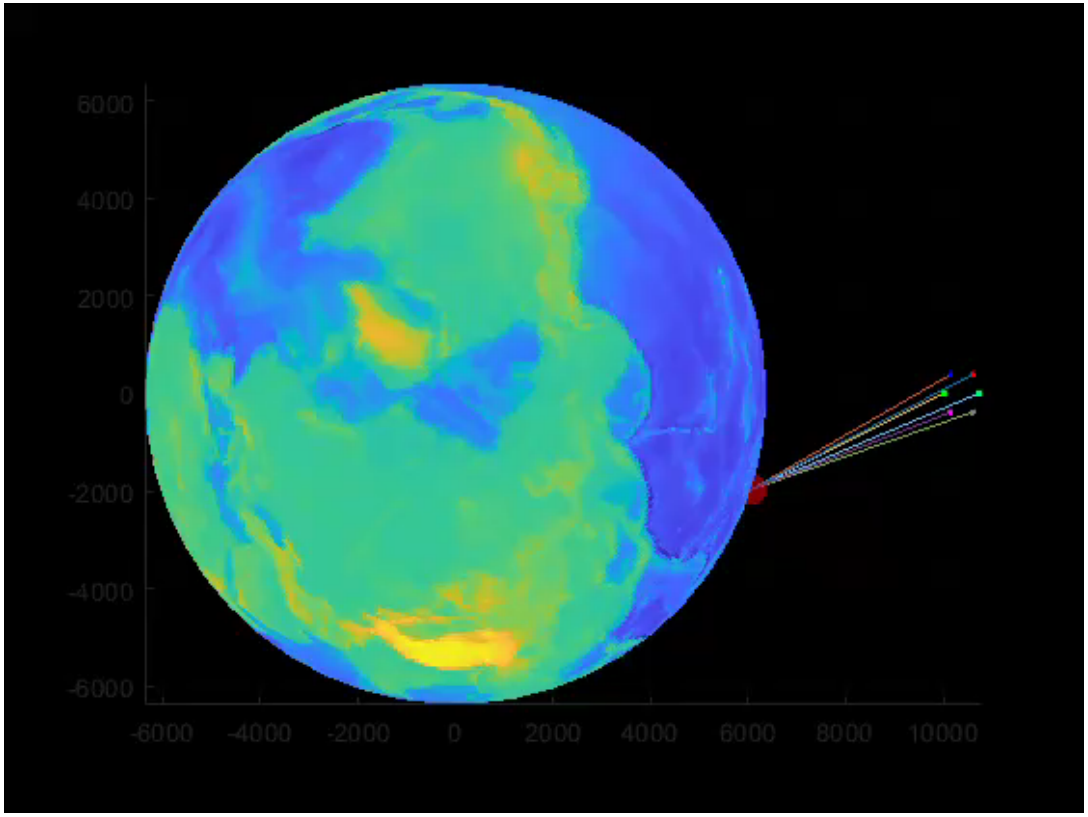
Flying Formation



Credit: JPL CAST Swarm Project

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Motivation

Classic control approaches
Main stream control approaches such as MPC, Sequantial Convex Optimization fail in the situation where:
1. Large number of spacecraft are presented
2. Optimization involved with full nonlinear dynamics

In this situation:

- **Convergence is not guaranteed and is hard to find a bound for the objective function.**
- **Also, Collison constraints make these problems harder to address**

- **How to deal with these situations is an important problem that needs to be addressed.**

- **ML-based approaches showed promising results in dealing with high dimensional problems aka self-driving cars**
- **Explore and exploit better in the parameter space**

- Basic problem formulation
- Closed form solution
  - Establish some baselines and add complexity on it
  - Still give us good solutions and that is not obtainable with other schemes.
  - Speed pre-learning with ML. Using set of weights
    - Imitation learning
  - Setting those weights
  - Treating as a black box
- Learning has been done before.
- CWH equations is used a first step.
- Generate dataset – certain controllers and see the results of RL with that

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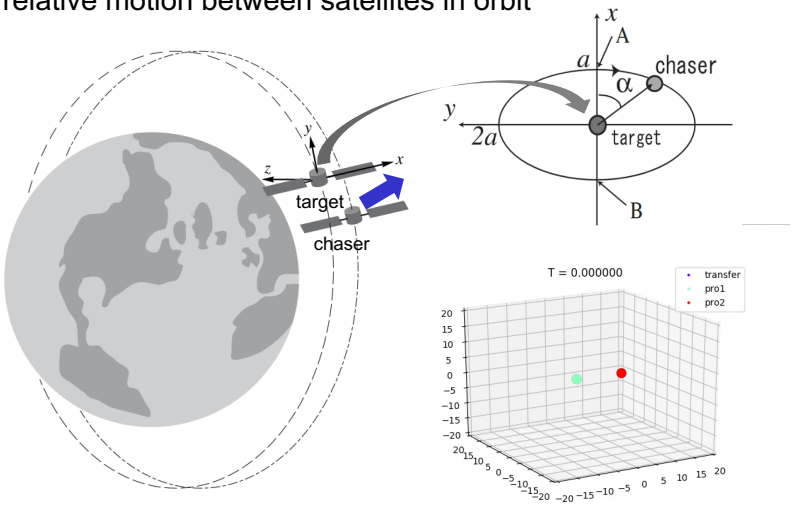
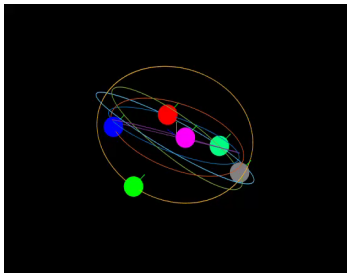
Data-Driven (ML) Trajectory Planning

The relative motion between satellites in orbit



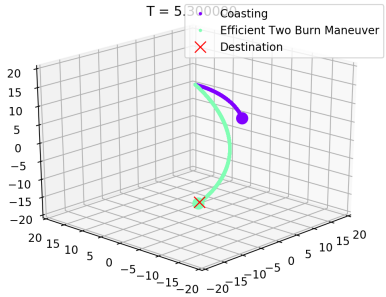
Passive Relative Orbits (PRO) transfer.

S. R. Alimo et al. “Machine Learning Approaches for General Satellite Maneuvers”. NASA Goddard AI Workshop 2018



Credit demo for JPL-CAST, Kiss Workshop

Formation flying is the flying of many satellites in close proximity (<10km distance). E.g., it can be used for multispacecraft distributed interferometers flying in formation to enable imaging at microarcsecond resolution.



Two-burn maneuver with Delaunay-based optimization (deltaDOGS).

S. R. Alimo et al. “Delaunay-based Derivative-free Optimization via Global Surrogates”. JOGO 2018

The goal is to maximize the science under some constraints such as fuel and time budget.

- Can formation flying be done more fuel-efficiently in the general case?

- Can we compute formation flying trajectories on-satellite, instead of on-the-ground?

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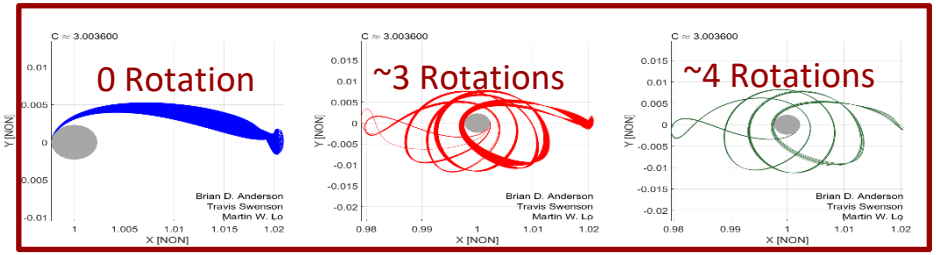
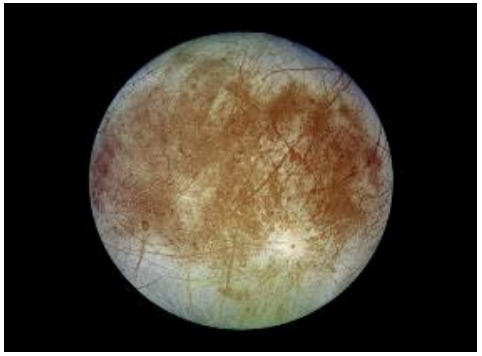
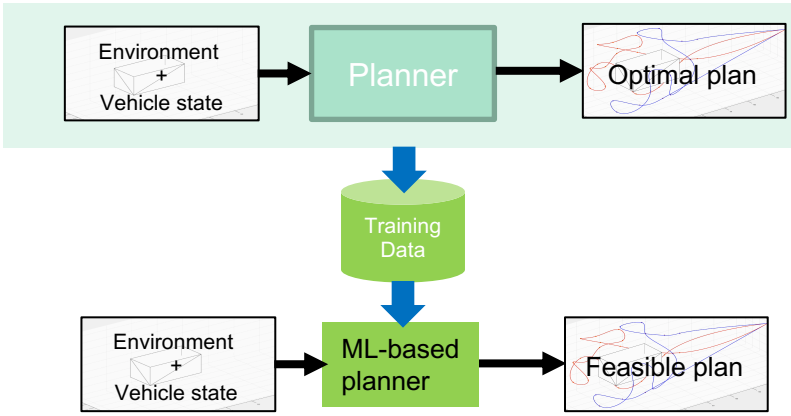
ML based planner for lander missions

Orbit Classification





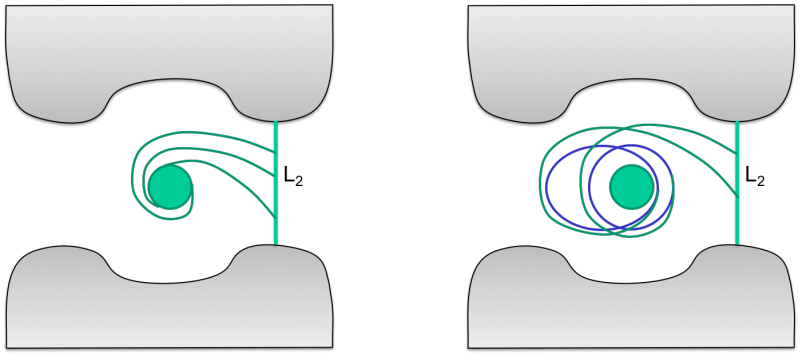


H. Ono et al. AAAI'19

Optimal planning often involves solving a nonlinear ODE and NP-hard problem.

Europa Landing Approach

Europa Capture Approach



M. Lo, B. Anderson, S. R. Alimo, Y. Chen, Y. Yue under preparation. 2019

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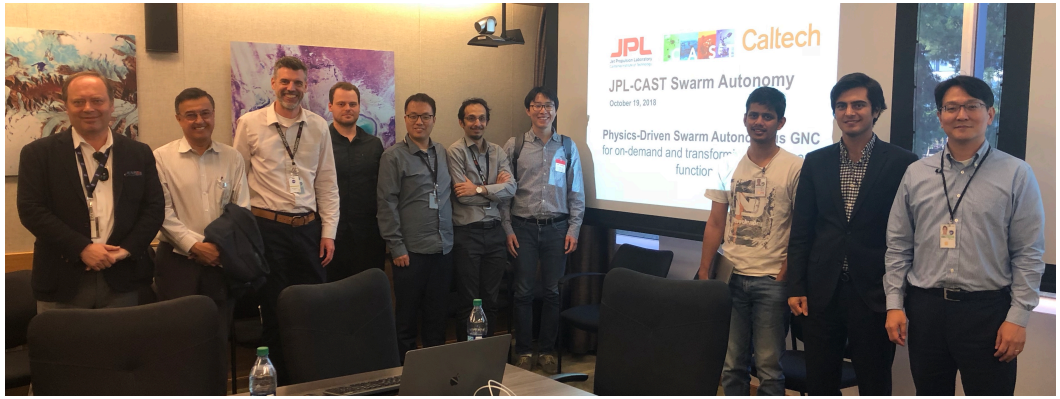
Acknowledgments

- JPL management: David Hanks, Navid Dehghani, Fred Hadaegh, Edward Chow, Adrian Stoica, Anthony Barrett, Micheal Wolf, Navid Dehghani, Rebecca Castano
- JPL team: Changrak Choi, Ravi Lanka, Hiro Ono, Ali Agha, Brian Kahovic, Amir Rahmni, Saptarshi Bandyopadhyay
- Deep Learning group 393K
- ML, AI, Robotics group
- JPL interns: A. Hess, J. Margoliash, Mitch Kennedy, Ameera Chowdhury



- CAST faculties: Soon-Jo Chung, Yisong Yue, Anima Anandkumar, Aaron Ames, Morteza Gharib
- CAST team: Kyunam Kim, Vincezo Capuano, Petter Nilsson, Yuxin Chen, Salar Rahili, Alexei Harvard
- Aerospace Robotics Lab
- CAST interns: R. Bao, A. Ho, S. Hyung.

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Thank you.

Questions?